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OVERVIEW OF THE BENCH-SCALE TREATMENT TECHNOLOGY TEST PROGRAM NEW BEDFORD HARBOR FEASIBILITY STUDY

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NOTICE

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PURPOSE:

The purpose of this technical memorandum is to provide an overview of the treatment technology bench test program conducted for the New Bedford Harbor Superfund project. This technical memorandum serves as the cover document for the following reports which present the results of this program:

- "Feasibility Testing of In Situ Vitrification of New Bedford Harbor Sediments." (Battelle, 1988);
- "Laboratory Testing Results: KPEG Treatment of New Bedford Soil - Final Report." (Galson, 1988)
- "Dewatering Study of PCB Contaminated Bottom Sediment - New Bedford Harbor," (OHM, 1988)
- "Bench-Scale Testing of Biodegradation Technologies for PCBs in New Bedford Harbor (MA) Sediments." (Radian, 1989)
- "New Bedford Harbor Sediment B.E.S.T. Glassware Test Report." (RCC, 1988)

BACKGROUND:

Current Superfund legislation and EPA guidelines emphasize remedial alternatives that employ "alternative" or "innovative" treatment technologies which permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances. A multi-component approach was used in the New Bedford Harbor FS to select and evaluate remedial technologies for the treatment of marine sediments contaminated with PCBs and metals. The basic steps for this approach were: identification of site- and waste-specific characteristics; identification and screening of treatment technologies; and detailed evaluation of treatment technologies.

Numerous field studies conducted for New Bedford Harbor indicate that applicable treatment technologies will have to accommodate potentially large volumes of marine sediments ranging from fine grain silts and clays to sands. The PCB concentrations in the sediments range from a few parts per million to over 100,000 ppm. The sediment-metals (notably Cd, Cu, and Pb) concentrations, co-located with the PCBs, range from a few parts per million to over 7,000 ppm.

Technology types and process options for treating PCB- and metal-contaminated sediments and liquid waste streams in New Bedford Harbor were identified through numerous sources including trade periodicals; computer database searches; EPA Superfund guidance documents and funded studies; other FSs; and direct contacts with technology vendors (Table 1). In the subsequent screening step, technology types and process options were eliminated from further consideration on the basis of technical implementability with respect to the site and waste specific conditions found in New Bedford Harbor. Table 2 summarizes the technology types and process options that were retained for detailed evaluation. The identification and screening of treatment technologies for New Bedford Harbor has been described in detail in numerous published reports (Allen and Ikalainen, 1988; E.C. Jordan/Ebasco, 1987a,b)

The treatment technology types and process options retained from the screening process were evaluated using a set of three criteria established by EPA CERCLA FS Guidelines (USEPA, 1988): effectiveness, implementation, and cost. The evaluation criteria were applied to each treatment technology to the extent possible. Greater emphasis was placed on evaluating each technology in terms of implementation and cost since these criteria could be applied more readily to an individual technology. The effectiveness of a treatment technology to reduce the toxicity, mobility or volume of hazardous waste was evaluated. However, effectiveness measured in terms of attainment of regulatory criteria, advisories or guidance, and potential adverse impacts to public health and the environment are more readily applied to the remedial alternative level. Details on the evaluation of treatment technology types and process options have been reported elsewhere (E.C. Jordan/Ebasco, 1987c).

BENCH-SCALE TREATMENT TEST PROGRAM

Demonstrated performance on a bench-scale, pilot-scale, or full-scale was found to be a key indicator of the level of development for a particular treatment technology considered for New Bedford Harbor. Information and data from these demonstrations provided the basis for addressing the screening and evaluation criteria: technologies were screened out in cases where no performance data existed, or were retained where the available performance data suggested applicability to New Bedford Harbor.

Incineration as a sediment treatment technology has been thoroughly demonstrated at full-scale. Incineration is the most widely practiced and permitted method of destroying organic hazardous wastes. Three types of incineration systems were

TABLE 1
TREATMENT TECHNOLOGY TYPES AND PROCESS OPTIONS
IDENTIFIED FOR NEW BEDFORD HARBOR

MEDIUM	RESPONSE ACTION	TECHNOLOGY TYPE	PROCESS OPTIONS
Sediment	Treatment	Physical	Air Stripping Soil Aeration Carbon Adsorption Flocculation/Precipitation Evaporation Centrifugation Extraction Filtration Solidification Granular Media Filtration In-situ Adsorption Molten Glass Steam Stripping Liquified Gas Extraction Vitrification Particle Radiation Microwave Plasma Crystallization Dialysis/Electrodialysis Distillation Acid Leaching Catalysis
		Chemical	Alkali Metal Dechlorination Akaline Chlorination Catalytic Dehydrochlorination Electrolytic Oxidation Hydrolysis Chemical Immobilization Polymerization
		Thermal	Electric Reactors Fluidized Bed Reactors Fuel Blending Industrial Boilers Infrared Incineration

TABLE 1
TREATMENT TECHNOLOGY TYPES AND PROCESS OPTIONS
IDENTIFIED FOR NEW BEDFORD HARBOR
(Continued)

MEDIUM	RESPONSE ACTION	TECHNOLOGY TYPE	PROCESS OPTIONS
		(Thermal)	In Situ Thermal Destruction Liquid Injection incineration Molten Salt Multiple Hearth Incineration Plasma Arc Incineration Pyrolysis Processes Rotary Kiln Incineration Wet Air Oxidation Supercritical Water Oxidation
		Biological	Advanced Biological Methods Aerobic Biological Methods Anaerobic Biological Methods Composting Land Spreading
		In-situ Biodegradation	
		Physical Stabilization	Vitrifiction Chemical Grouts
		Dechlorination	

TABLE 2
TREATMENT TECHNOLOGY TYPES AND PROCESS OPTIONS
RETAINED FOR DETAILED EVALUATION

MEDIUM	RESPONSE ACTION	TECHNOLOGY TYPE	PROCESS OPTIONS
Sediment	Treatment	Physical	Solvent Extraction Solidification Liquified Gas Extraction Vitrification
		Chemical	Alkali Metal Dechlorination
		Thermal	Infrared Incineration Fluidized Bed Reactors Rotary Kiln Supercritical Water Oxidation
		Biological	Advanced Biological Methods

considered applicable for treating PCBs in New Bedford Harbor sediments and were therefore retained for remedial alternative development (Jordan/Ebasco, 1987c): infrared, rotary kiln, and fluidized bed. All three systems achieve similar, results but differ in materials handling and hardware design. Detailed descriptions of each incineration system are in the Jordan/Ebasco report (1987c).

The available bench-and pilot-scale performance data for many of the other sediment treatment technologies appeared promising for New Bedford Harbor, although the site-and waste-specific conditions under which the tests were run were often dramatically different from the conditions found at New Bedford. Based on these results, a bench test program was developed by E.C. Jordan/Ebasco to provide performance data specifically for New Bedford Harbor sediments. No treatment tests were conducted for the three incineration options. The results of the sediment treatment tests were used to determine the following:

- effectiveness of the treatment technologies on treating PCB and metal contaminated sediment and water from New Bedford Harbor

- potential material handling problems and process rate limiting features that might develop during scale up of the treatment technology

- refined cost estimates for treating New Bedford Harbor sediments

A bench test workplan was designed to serve as the request for proposals (RFPs) document sent to vendors identified as providing the specific technologies for bench testing (E.C. Jordan/Ebasco, 1987d).

RFPs were sent to 34 technology vendors. These vendors were selected on the basis of information provided by them in response to questionnaires sent out by E.C. Jordan/Ebasco. Of the 14 vendors which responded to the RFP, contracts were awarded to five on the basis of cost, and the technical quality of their proposals. Because of insufficient information supplied in the proposal submitted for testing supercritical water oxidation and the excessive cost of the proposed test, this sediment treatment technology was eliminated from further consideration at this point. The four vendors and their technologies who were selected to participate in the E.C. Jordan/Ebasco test program are shown in Table 3.

TABLE 3
BENCH--SCALE TESTS OF SEDIMENT TREATMENT TECHNOLOGIES
NEW BEDFORD HARBOR

TECHNOLOGY	SCALE	VENDOR	CONTACT
Solvent Extraction			
BEST Process	Bench	Resources Conservation Co. 3006 Northup Way Bellevue, WA	Lanny Weimer (301)-465-2887
Alkali Metal Dechlorination			
KPEG Process	Bench	Galson Research Corporation 6601 Kirkville Road East Syracuse, NY	Edwina Millisic (315)-463-5160
Vitrification (Modified In-situ)	Bench	Battelle Pacific Northwest Laboratories Richland, WA	Craig Timmerman (509)-376-2252
Advanced Biological Treatment (Aerobic)	Bench	Radian Corporation 5103 W. Beloit Road Milwaukee, WI	Chuck Applegate (414)-643-2768
Sediment Dewatering			
Plate & Frame Filter Press	Bench	OH Materials Corp. 1090 Cinclare Drive Port Allen, LA	Chuck Bearden (504)-389-9596

In addition to the four technology vendors selected through the RFP process, a fifth vendor, OH Materials, was added to the program. A bench-scale [sediment] dewatering test using the plate and frame technology was conducted to determine the efficiency of this process in dewatering sediments as a precursor step to treatment or disposal.

With the exceptions of OH Materials and Battelle, each technology vendor selected for the bench test program received two types of composite sediment samples collected from New Bedford Harbor: sediments with PCB concentrations between 1,000 and 30,000 ppm (high-level); and sediments with PCB concentrations less than 500 ppm (low-level). OH Materials received a sample of sediment collected from an area of low PCB contamination (<100 ppm). No chemical analyses for PCBs was conducted on this sample since the purpose of the test was to determine the feasibility of physically dewatering the sediment. Battelle received only a high level sediment sample for testing. Sediment sample volumes sent to the vendors ranged from 1 to 3 gallons depending on their specific process needs.

Prior to shipment the composite samples provided to each vendor were analyzed for PCBs (USEPA Method 608: GC-ECD, PCB congeners), Target Compound List (TCL) organics (USEPA contract laboratory program caucus organic protocol [CLP-COP]), metals (USEPA contract laboratory program caucus inorganic protocol [CLP-CIP]), grain size (ASTM P-421, 422), and percent moisture (ASTM D-2216). Aliquots of the treated material were analyzed by a USEPA CLP Laboratory for comparison with the vendors' results.

Since PCBs are regulated under the Toxic Substances Control Act (TSCA), 40 CFR Part 761, all vendors participating in the bench test program were required to have TSCA R&D permits (48 FR 13182). These permits, issued by the EPA Regions, allowed the vendors to conduct tests on PCB-contaminated material at their facilities.

The E.C. Jordan/Ebasco treatment technology bench test program began in January 1988 with the collection of the sediment samples from New Bedford Harbor. The original program schedule allowed 10 to 12 weeks for each of the vendors to complete their tests and submit reports. Because of delays in obtaining their TSCA permits, only two of the five vendors selected had completed their test programs by August 1988. One of the selected technology vendors, CF Systems, was unable to obtain a TSCA R&D permit within the time constraints of the bench test program and ultimately withdrew.

Two additional treatment technology tests were conducted for the New Bedford Harbor project: 1) a bench-scale study ofsolidification/stabilization of New Bedford Harbor sediments conducted by the US Army Corps of Engineers (USACE) at their Waterways Experiment Station (WES) as part of the USACE's Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; and 2) a pilot-scale demonstration of CF Systems liquified gas extraction technology conducted at New Bedford Harbor in the fall of 1988 under the auspices of the USEPA SITE program. A brief summary of these studies is discussed below. Details of these studies are reported elsewhere (Myers and Zappi, 1988; SAIC, 1988).

The results of the sediment treatment test program are in Table 4. A brief description of each sediment treatment technology and general comments regarding test results are discussed in the following paragraphs. Details on these technologies and the test results are contained in the report references cited.

Solvent Extraction - BEST Process. Resource Conservation Company (RCC) conducted a bench-scale study of their BEST. solvent extraction process on a sample of New Bedford Harbor sediment (RCC, 1988a). The BEST process employs the inverse miscibility property of the solvent triethylamine (TEA) to separate PCB-contaminated sediments into PCB/oil, water, and solids fractions. Sediments containing PCBs are mixed with TEA at a temperature of about 40 degrees Fahrenheit. At this temperature, the TEA freely mixes with the water and the PCB/oil fraction of the sediment matrix. After a suitable reaction period, the extracted solids are removed from the reaction mixture by centrifugation. The remaining liquid containing water, TEA, and PCB/oil is then heated to 150 degrees Fahrenheit. At this elevated temperature, the water separates from the TEA/PCB/oil fraction. The TEA solvent is recovered by steam stripping from the PCB/oil fraction and reused. The PCB/oil fraction is disposed of, usually by incineration at a permitted, offsite facility.

Results of the BEST test are summarized in Table 4. PCB removal efficiencies of +99% were achieved after three extraction stages for both high-level and low-level sediment samples tested (initial PCB concentrations of 5,800 and 420 ppm, respectively). PCB concentration in the treated residue of the low-level sediment was 11 ppm. However, the concentration of PCBs in the treated residue of the high-level sediment was 130 ppm. As a result of this finding, RCC conducted an additional bench test on New Bedford Harbor sediment to further optimize process parameters. In this second test, a sediment sample containing 11,000 ppm of PCBs was reduced to 16 ppm after six extraction stages (RCC, 1988b).

An EP Toxicity test was conducted by RCC on the treated New Bedford Harbor sediment. Results indicated that leachate concentrations of heavy metals were well below the allowable maximum concentrations. This apparent immobilization of the metals is presumed to be due to the alkaline (i.e., pH greater than 9) nature of the treated residue. The implication of this finding is that secondary treatment (e.g., solidification) of the solvent-extracted sediment may not be necessary to immobilize the heavy metals.

TABLE 4
RESULTS OF BENCH- AND PILOT-SCALE TESTS OF TREATMENT TECHNOLOGIES
CONDUCTED FOR NEW BEDFORD HARBOR

TECHNOLOGY	RESULTS OF TREATMENT TEST	ADVANTAGES	DISADVANTAGES	RETAINED
Solvent Extraction (B.E.S.T. Process)	o 99.1% reduction in PCBs in low level (780 ppm) sediment after 3 extraction stages o 99.4% reduction in PCBs in high level (4,300 ppm) sediment after 3 extraction stages o 94% reagent recovery o 90% solids recovery o Apparent immobilization of metals	o High PCB removal o Not limited by moisture content o Energy efficient o Proven in field test o Commercial units available	o TEA solvent is flammable o Secondary treatment for metals may be required	Yes
Alkali Metal Dechlorination (KPEG process)	o 99.8% removal of PCBs in low level (440 ppm) sediment after 9 hours o 99.8% removal of PCBs in high level (7,300 ppm) sediment after 12 hours o 75% reagent recovery (min) o 43% solids recovery (dry wt)	o High PCB removal o Biphenyl ether end product not acutely toxic, and does not bioaccumulate.	o Low reagent/sediment recovery suggests material handling problems need to be overcome o Secondary treatment necessary for metals o Moisture inhibits dechlorination reaction o No commercial process available at present time	No
Solidification/ Stabilization	o Chemical stabilization properties of the three technologies tested were similar o Hardened material exceeded 50 psi USEPA-OWSER standard o PCB leachability reduced by 10X to 100X (depending on formulation)	o Effective stabilization of PCBs o Effective stabilization of cadmium and zinc o Numerous commercial processes available	o Apparent mobilization of certain heavy metals o No information or data on long-term structural integrity of solidified material	Yes

TABLE 4 (Continued)
RESULTS OF BENCH- AND PILOT-SCALE TESTS OF TREATMENT TECHNOLOGIES
CONDUCTED FOR NEW BEDFORD HARBOR

TECHNOLOGY	RESULTS OF TREATMENT TEST	ADVANTAGES	DISADVANTAGES	RETAINED
Solidification/ Stabilization (continued)	o Cadmium and zinc leachability significantly reduced; eliminated in one process o Copper and nickel apparently mobilized			
Vitrification	o 99.94% destruction of PCBs o 99.9985% DRE (soil-to-offgas) o Metal concentrations in TCLP extract below regulatory limits	o Effective destruction of PCBs and encapsulation of metals	o High energy requirements o No commercial units available at this time	No
Liquified gas extraction (propane)	o 97% reduction of PCBs in low level (<400 ppm) sediment after 10 passes through unit o 96% reduction of PCBs in high level (>2,000 ppm) sediment after 6 passes through unit o 93% solids recovery	o High PCB removal	o Further development needed to address problems with materials and system operating parameters experienced during pilot test o No commercial units available at this time	No
Advanced Biological Methods (aerobic)	o Significant degradation of lower chlorinated congeners (di- and trichlorobiphenyls) o No degradation of higher chlorinated PCB isomer groups	o Insufficient data to assess advantages of this treatment process relative to other treatment processes	o Incomplete destruction of PCBs o Insufficient data to determine process rates and process design parameters	No
Plate and Frame Filter Press	o 38% solids sample dewatered to 62% solids cake o Compression strength of filter cake measured at 1.25 tons per square foot.	o Effective method of sediment dewatering o Commercial units readily available	o Batch Operation	Yes

RCC bench test protocols were developed to simulate the process dynamics of their 100-ton-per-day pilot-scale treatment unit, which was used successfully to remediate a Georgia Superfund site. Therefore, it is expected that these bench-scale results can be achieved in a full-scale unit deployed for New Bedford Harbor.

At the present time, RCC is testing a different method of processing using Littleford™ rotary washer-dryer units. These units are readily available and are used extensively in the chemical processing industry. One major advantage of this processing system is that sediment-solvent mixing is more uniform, thereby increasing the extraction efficiency per stage (or wash cycle). In addition, the sediment is not moved from one reaction stage to the next, which simplifies material handling. RCC is currently conducting tests using this new processing hardware. Pilot tests of this hardware system using New Bedford Harbor sediments would be necessary prior to implementation.

The BEST process was retained as a viable solvent extraction technology for treating New Bedford Harbor sediment. Results of the solvent extraction bench test indicate that efficient removal of PCBs is possible. This technology is also commercially available at the present time.

Costs for treating New Bedford Harbor sediment using the BEST process were estimated by RCC to be $70 per ton and $143 per ton, based on 450,000 cy and 46,000 cy of sediment treated, respectively.

<u>Solvent Extraction - Liquified Gas Extraction</u>. In July 1988, the EPA Superfund Innovative Technology Evaluation (SITE) program selected New Bedford Harbor as the demonstration site for a pilot-scale test of CF System's liquified gas extraction process (SAIC, 1988). The demonstration took place at New Bedford Harbor during the fall of 1988. CF Systems uses propane, which is heated and compressed to a liquid state. The combined properties of gas diffusivity and liquid solvency allow the liquified propane to mix readily with PCB-contaminated sediment, extracting the PCBs.

Results of the pilot test are summarized in Table 4. Although PCB removal efficiencies of +96% were achieved, multiple passes (up to 10) were required to obtain these results. Based on the test data, it was estimated that six passes would be required to treat a 2,450-ppm sediment to a level of 100 ppm. An additional nine passes would be required to achieve a level of 10 ppm, the apparent lower limit of treatment for the CF Systems process based on current operating conditions and equipment configuration (SAIC, 1989). Multiple passes to achieve high removal efficiencies would significantly reduce throughput rates for this extraction technology. A material balance of the system indicated that 93 percent of the total solids mass was recovered, but only 44 percent of the known mass of PCBs was accounted for in effluent streams (SAIC, 1989).

A number of equipment and materials handling problems were experienced during the pilot demonstration, including the following (SAIC, 1989):

- plating of PCBs on the internal surfaces of the extraction vessels and piping
- foaming of propane
- carry over of solids in the extract samples
- fluctuations in solvent flow and solvent/feed rates
- mean operating capacity of approximately two (55 gallon) barrels per day versus a claimed feed capacity of 20 barrels per day

Costs for treating New Bedford Harbor sediment using the liquified gas extraction process are not available at this time.

Liquified gas extraction was not retained at this time as a possible option for treating New Bedford Harbor sediments using solvent extraction. Problems with materials handling, system operating parameters, extraction efficiencies, and low throughput rates observed during the New Bedford pilot demonstration need to be resolved prior to full-scale implementation.

Alkali Metal Dechlorination. Galson Research Corporation (Galson) conducted a bench-scale study of their KPEG process (Galson, 1988a). In the KPEG process, potassium hydroxide/polyethylene glycol (KPEG) reagent is mixed with PCB-contaminated sediments to form a slurry. The mixture is heated, causing the dechlorination of PCBs to biphenyl ether. The reaction products of this process are reportedly nontoxic and nonmutagenic (Galson, 1988a).

Results of Galson's bench test, summarized in Table 4, indicate that PCB removal efficiencies of +99% were achieved for both the high- and low-level sediment samples tested (initial PCB concentrations of 7,300 and 440 ppm, respectively). PCB concentration in the treated residue was 3.5 ppm for the high-level sediment sample after 12 hours of treatment, and 0.7 ppm for the low level sediment sample after 9 hours (Galson, 1988a). These results, however, are based on a sediment-solids recovery averaging only 43 percent. Reagent recoveries ranged from a high of 110.8 percent for the polyethylene glycol (PEG) reagent to a low of 75.5 percent for the dimethylsulfoxide (DMSO) reagent. The relatively low reagent and sediment-solids recovery suggests that material handling problems would have to be addressed in a full scale operation.

Costs for treating New Bedford Harbor sediment using the KPEG process were estimated by Galson to be $98 per ton and $120 per ton, based on 500,000 cy and 50,000 cy of sediment treated, respectively.

In general, the KPEG process has been demonstrated to be effective at removing PCBs from soil matrices at the bench-scale level. However, there are several unresolved issues concerning this process: (1) other than the reagents, no data or information exist on the chemical composition of the reaction products which could potentially be hazardous; (2) toxicity testing of these products needs to be investigated further; (3) materials handling would appear to be a major problem in terms of solids and solvent recovery; (4) the lengthy reaction times for this process (hours) raise questions regarding throughput rates; and (5) unlike the CF Systems pilot demonstration, the KPEG process has not been demonstrated on a pilot-scale level that simulates an <u>integrated</u> system of reactor hardware and material handling.

Alkali metal dechlorination was not retained for New Bedford Harbor. The disadvantages of this process, particularly the lack of information and data from a well-designed pilot study, outweigh the bench-scale performance achieved for New Bedford.

<u>Solidification</u>. A bench-scale study of solidification/stabilization was conducted by USACE as part of their EFS (Myers and Zappi, 1989). Composite sediment samples containing PCBs and metals were processed using three solidification/stabilization technologies: (1) Portland cement; (2) Portland cement with Firmex proprietary additive; and (3) Silicate Technology Corporation proprietary additive. The treated sediments were subjected to physical strength and chemical leach tests to evaluate the effectiveness of solidification/stabilization.

Results of the solidification/stabilization study are presented in Table 4. In general, solidification/stabilization was found to be an effective method for immobilizing PCBs, cadmium, and zinc in New Bedford Harbor sediments. The apparent mobilization of copper and nickel may be due to changes in the interphase transfer processes for these two metals; however, this has not been confirmed. It is anticipated that, given the numerous commercial processes available, a formulation of solidifying agents is available to immobilize all heavy metals.

Costs for treating New Bedford Harbor sediment using solidification/stabilization range from $82 per ton to $97 per ton (Jordan/Ebasco, 1987c).

Solidification/stabilization was retained as a viable sediment treatment technology for New Bedford Harbor. This technology could be applied as a primary treatment for PCB and metal contaminated sediments, or as a secondary treatment for metals following a technology such as incineration or solvent extraction, which would remove PCBs.

Vitrification. Battelle Pacific Northwest Laboratories conducted a bench-scale test of modified in-situ vitrification of New Bedford Harbor sediments (Battelle, 1988). In the vitrification process, electric current is applied to molybdenum electrodes inserted in PCB-contaminated sediment. Temperature in excess of 3,600 degrees Fahrenheit destroys the organics (PCBs) and encapsulates the metals in a glass-like solid matrix.

Results of Battelle's vitrification bench test are summarized in Table 4. Vitrification was found to be a highly efficient method of destroying PCBs in New Bedford Harbor sediments. In addition, vitrification provided an effective method of immobilizing heavy metals by encapsulating them in the glass-like residue.

Costs for treating New Bedford Harbor sediments using vitrification were estimated by Battelle to be $310 per ton and $290 per ton, based on 50,000 cy and 500,000 cy of sediment treated, respectively.

Although results of the bench test were favorable, vitrification was not retained as a viable technology for treating New Bedford Harbor sediments. Modified in-situ vitrification has not been demonstrated on a pilot- or full-scale for sediments or other high-moisture-content materials. Because vitrification could not be applied as an in-situ treatment method at New Bedford Harbor, a processing system would have to be developed to vitrify batches of sediment. Currently, there has been no hardware design completed. This fact, coupled with the very high costs of treatment, make vitrification less attractive than incineration.

Advanced Biological Treatment. Radian Corporation conducted a bench-scale study of aerobic biological treatment of New Bedford Harbor sediments containing PCBs (Radian, 1989). Advanced biological treatment of sediment PCBs would be conducted in hardware systems similar to those used for biological treatment of wastewaters in municipal and industrial waste treatment plants. These systems allow for enchancement and control of biological degradative mechanisms to a greater degree than natural, *in situ* degradation.

Cultures of microbes from sediment sources in the New Bedford Harbor estuary and from an anaerobic digester used to treat PCB-contaminated sewage sludge were acclimated to biphenyl as the only carbon source. The enriched cultures were then switched to PCB-contaminated sediment for test purposes. Sediments from two specific sources were used to test PCB degradation. One source contained relatively high concentrations of PCBs (>3,000 ppm), and the second source contained lower concentrations of PCBs (1,000 ppm). Presumptive testing was done to determine if there was a net loss of PCBs within the treatment system. Confirmation testing was done to determine if any net loss observed was due to microbial metabolism.

The presumptive tests consisted of operating laboratory-scale aerobic reactors in a daily draw and fill mode with an average hydraulic retention time of 14 days. The results of the presumptive tests indicated a reduction in PCB concentration was obtained in both the high and low PCB level sediments (Radian, 1989):

- The overall reduction of PCBs ranged from 13-15% for the high level sediment reactors, and 30% for the low level sediment reactors;
- By isomer groups, the PCB reduction was greater for the less chlorinated species. For the high level sediment, dichlorobiphenyls were reduced 62-70% and trichlorobiphenyls 32-40%. There was little removal of the higher chlorinated species;
- For the low level sediment, some reduction in the levels of tetra- and pentachlorobiphenyls were noted along with the removal of di and tri isomer groups. Dichlorobiphenyls were reduced 79-82%, trichlorobiphenyls 48%, tetrachlorobiphenyls 14%, and pentachlorobiphenyls 6%.

The goal of the confirmation tests was to determine the amount of PCBs removed by biological mechanisms by performing a PCB mass balance around the batch operated reactors. However, the initial PCB level in the control digester was found to be twice that in the test reactors. Therefore, the amount of PCBs removed by biological mechanisms could not be differentiated from the amount of PCBs removed by physical/chemical processes (Radian, 1989). The pattern of PCB reduction in the confirmation tests was similar to that observed in the presumptive tests (Radian, 1989):

- The overall reduction of PCBs ranged from 27-70% for the high level sediment reactors. Dichlorobiphenyls were reduced 83-100% and trichlorobiphenyls were reduced 64-87%. For the highler chlorinated groups, the reduction ranged from 0-7% in one reactor to 51-100% in another reactor. The reason for the wide range in percent removal of these higher chlorinated groups is unknown;

- For the low level sediment reators, dichlorobiphenyls were reduced 39-50%. Little or no removal of higher chlorinated groups was observed.

Radian noted that the formaldehyde added to the control reactors to inhibit biological growth affected the PCB analyses. Initial PCB concentrations in the control reactors were approximately double the initial PCB levels in the test reactors.

The results of the Radian tests indicate that a microbial culture capable of degrading PCBs in a brackish water environment such as the estuary in New Bedford Harbor can be developed. However, these results also indicate that only dichlorobiphenyls and trichlorobiphenyls were degraded to a significant extent under conditions simulating a full-scale aerobic system designed to treat large volumes of sediment.

The scope of work conducted by Radian did not include the generation of kinetic data on PCB destruction or the optimization of process parameters. Radian did suggest several potential mechanisms for enhancing the rate of PCB degradation: increasing the desorption rate, enhancing cometabolism, and manipulating reactor operation modes and population characteristics. However, Radian also noted that none of these methods would be practical for treating New Bedford Harbor sediments unless a mechanism was developed for degrading all PCB isomer groups.

Costs for treating New Bedford Harbor sediment using advanced biological methods are unavailable due to insufficient data on these processes.

Based on preliminary results, advanced aerobic biological treatment was not retained as a viable treatment technology for New Bedford Harbor. Considerable research and process development is needed to understand the mechanisms and kinetics that are prerequisites to designing and implementing a full-scale operation. Lack of specific information makes it difficult to compare the effectiveness, implementation, and cost of biological treatment with other treatment technologies that are further developed.

Sediment Dewatering. OH Materials (OHM) Corporation conducted a bench-scale dewatering test on New Bedford Harbor sediments collected in the upper estuary (OHM, 1988). Although dewatering technologies are proven, this test was conducted to determine if existing equipment could effectively dewater New Bedford Harbor sediment. The test was conducted using a bench-scale chamber plate and frame press. This device simulates the full-scale, trailer-mounted units commercially available.

Results of the dewatering test, summarized in Table 4, indicate that New Bedford Harbor sediments can be effectively dewatered in excess of 50 percent solids using this technololgy. Compression strength of the sediment filter cake was 1.25 tons per square foot.

The costs for dewatering New Bedford Harbor sediment was estimated by OH Materials to be $45 per cubic yard ($31 per ton) based on 600,000 cy in situ.

Dewatering of New Bedford Harbor sediments would be a necessary first step prior to implementation of treatment technologies (e.g., incineration).

CONCLUSION:

Based on the results of these bench-scale treatment tests, solvent extraction and stabilization/solidification were retained as viable sediment treatment technologies for New Bedford Harbor. The results of the sediment dewatering test indicated that conventional dewatering technologies will be effective in dewatering the sediment as a precursor step to treatment and/or disposal. These treatment technologies, along with incineration, will be used in the development of remedial alternatives which achieve the remedial objectives or clean up goals developed for the New Bedford Harbor site.

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